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TOPICAL DISCUSSION ON "FEED WATER HEATERS."

MR. J. SHIRRA, in opening the discussion, said that of all the auxiliary appliances for improving the economy of the steam engine, the feed heater was perhaps the simplest, the most universally applicable, the surest, and the safest. The great loss of energy which necessarily occurred in the simplest type of engine and boiler by waste heat might be considerably lessened by a well-designed feed heater, and great and manifold benefits besides might be conferred by it.

The principal losses of heat were in the chimney and in the eduction pipe, the heat carried away in the furnace gases and in the exhaust steam. Either of these losses might be diminished by a feed heater, but that which tried to save the waste heat in the gases was more usually called an economiser, to distinguish it from that which tried to recover some of the sensible and latent heat in the exhaust.

The economiser was really an extension of the boiler; a battery of tubes in the flues through which the cold feed was passed before entering the boiler or steam generator proper, which absorbed some of the heat from the gases which the hotter heating surface of the boiler could not conveniently take up, the rate of transmission of heat depending on the difference of temperature of the heating body, and that being heated; so the comparatively cool economiser got the benefit of the heat otherwise lost.

In water-tube boilers such an arrangement was found beneficial because it brought out the strong point of these boilers—their water-heating powers—and to keep a large portion of the heating tubes free from steam, as in the economisers fitted to Belleville marine boilers, rendered all the surface of these tubes efficient, and prevented the disturbance due to the unstable mixture of steam and water that occurred in the steam part of the boiler. But when we remembered that the heat required to raise water from ordinary feed temperature to boiling point was only about a fourth of that further required to evaporate it we could see that this benefit was of very limited application.

Green's economiser was the favourite form in which this adjunct was applied to Lancashire boilers, in the form of vertical cast-iron water tubes, around which the smoke and furnace gases circulated. But it soon lost its efficiency unless the outside surfaces were kept free from soot and deposit, the cool metal condensed the tarry matters in the smoke to a greater extent on its surface than occurred in the hotter boiler; consequently, a perpetually-moving scraper device had to be kept going to keep the water-tubes clean—an object lesson to those partisans of the water-tube boiler proper who claimed entire immunity from such deposits on their tubes.

A feed heater, moreover, to give the full benefit possible, should be arranged to eliminate the dissolved air from the feed, as well as heat it, before introducing it into the boiler, and this economisers failed to do. If the corrosive action of the air so entering did not act in the boiler, it acted in the economiser itself, which was really part of the boiler—the corrosion and pitting of the economisers in Belleville marine boilers was notorious—and the top or air-ends of Green's economiser tubes, and the bolts for securing the caps, suffered severely from the same action. If the heating surface in the boiler was sufficient to cool the effluent to 400° or 500° F., as it ought to be, little benefit could be derived from feed heaters of this type, the heat in the chimney being all profitably employed in producing draught.

The feed heaters which seemed to him so beneficial and so easily applied to all plants were those in which steam, exhaust or other, was used to heat the feed. Originally used, probably, only to save some of the heat in exhaust steam, the secondary benefits observed to flow from or accompany this were so great that feed heaters, which make no direct saving of this sort, were largely used.

In marine engine practice the temperature of the feed in the hotwell might be from 120° to 140° F.; that of the exhaust steam in the eduction would not be much more, perhaps 160° F., the temperature of saturated steam with an absolute pressure of about 5 lbs. per square inch. Consequently little saving was possible by heating feed with the exhaust steam, though it had been tried occasionally.

In Weir's heater, the steam was taken from the low pressure cylinder steam chest, and consequently was at a much higher pressure and temperature than in the eduction pipe. We lost the work it would have done in the low pressure cylinder, but recovered all the energy left in the steam used, after having already obtained some work from it in the high pressure and intermediate cyclinders. The exhaust from the independent feed pump, which usually formed part of the system, communicated with the heater steam pipe, and was available for heating, as also might be the steering engine exhaust, so that the steam supplied to the heater was of a high temperature and might be fairly "wet." The contained moisture was returned direct to the boiler in the feed instead of passing through the low pressure cylinder and lowering its efficiency. If we supposed the steam to be of 15 lbs. gauge pressure with 10 per cent. of water in it and the feed to be heated 80° F.—say, from 125° to 205° 1 lb. of wet steam would heat about 111 lbs. of water; that was one-twelfth of the steam generated would never reach the low pressure cyclinder, but having parted with at least two-thirds (in a triple-expansion engine) of the available work in it, would return to the boiler with its surplus energy intact, instead of its having been dissipated in the condensing water.

If we could use all the steam thus to heat feed water the low pressure cylinder might be dispensed with, and we would have the fabled "perfect engine." Plausible schemes for "steam feed" have been put forward, but since if all the steam were used for heating, there would be no other feed-water to heat, the idea resolved itself into an absurdity. In a non-condensing engine the feed could always be heated up to the temperature of the exhaust and a further supply of hot water obtained, where needed for manufacturing purposes, by the adoption of a heater worked by exhaust steam. With proper arrangements, these heaters would also purify the water from calcareous matter, and to some extent from grease. Many such devices were in the market, feed heaters and purifiers, for with waters containing lime carbonate the heat drove off the carbonic acid in the water and precipitated the lime scale, which could be filtered out or removed before entering the boiler, or the purified water applied to other purposes. The lime sulphate which occurred in sea and many other waters was more intractable, but if sea water was sufficiently heated, say, to 290° F., or the boiling temperature under 40 to 45 lbs. gauge pressure, the sulphate would be thrown out of solution also; and it had been proposed, instead of using evaporators to make up fresh feed at sea, to simply heat water to this temperature under pressure in a seperate vessel, when the scale would precipitate out, and the supernatant water, containing soluble salts only, could be used as feed.

This principle was acted on in any modern feed heaters where the heating took place in the boiler steam space, or in a chamber connected therewith. The calcareous matter was set free and caught in a series of trays or trapped somehow, while the hot and purified water entered the boiler amongst the steam. When this heating took place in a seperate chamber, any air in the feed was liberated therein, and could be drawn off by a cock and pipe to the condenser hotwell with, of course, a quantity of high pressure steam along with it; but probably there was no advantage in so drawing off the air—it was not so much the air in the steam space that corroded the boiler as that in the water or in its nascent condition at the instant of liberation.

Delivering the feed in spray or over a cataract of trays in the steam space gave no direct thermal saving, but secured the feed being at boiling temperature when it mingled with the boiling water. This was of great advantage to the boiler, as it ensured an equal temperature throughout, and freed it from the racking of differential expansion. This benefit to the boiler was so marked, that live steam feed heaters—where no heat saving was looked for, the heat being taken from the boiler direct,—were much used, the arrangements resembling surface condensers, as the direct contact of exhaust steam resembled a jet condenser. Such heaters would deliver water at boiling temperature and free it from air, and possibly some grease also, by suitable arrangements, but could not return to the boiler all the heat they had taken from it, some being always lost by radiation and conduction from the pipes. Yet it had nearly always been observed that such heaters increased the efficiency of the boiler notably. It could only be by improving the circulation in the boiler that such gain occurred—most boilers could have their circulation improved,—but probably with a well-designed boiler the gain was not much. If the same beneficial effect was produced by simply introducing the feed into the steam space, as seemed to be the case, this coal-saving of a live-steam feed heater should be produced by simply putting the feed check valve at a high level on the boiler, with a suitable nozzle or discharge inside to prevent the hammering that might occur in the pipe through "steam loops" forming in it. The heaters worked by exhaust or intermediate steam showed this improvement also, over and above the actual saving in energy they gave; though as they could not heat the water to the boiler temperature it was not so marked.

In the steamships "Inchdune" and "Inchmarlo", whose engines held the record for coal efficiency in marine engineering —having given I. I. H. P. for less than 1 lb of coal per hour,— the two systems were combined, the feed being first raised in a Weir's heater to about 223°F. and then in a Kircaldy's live steam heater to a further 400°, the boiler pressure being 260 lbs., and the boilers of the Scotch type. There was also a third device used, the entering feed water being made to induce a flow from the boiler bottom which mingled with the hot feed, and was discharged through the check valve in the higher part of the water space.

The economy of using feed heaters was, therefore, indubitable, but to some extent was inexplicable and incalculable. Accurate experiment and full statement of the conditions experimented under, would supply us with data which might lead to important conclusions, for the phenomena of ebullition were really far from being understood. He regretted that he could not place such before members, but from experience with Weir's feed heater he could say, qualitatively only, that it greatly increased the steaming power of a boiler.

Mr. Hector Kidd said that the selection by the Council, "Feed-Water Heaters," as the subject for a topical discussion, seemed to him an appropriate one to follow immediately after the recent discussion on water-tube boilers, as they were an important adjunct to any class of boiler, increasing their evaporative efficiency, and also tending to lengthen their life by reducing the wear and tear caused by differences of temperature.

That feed water heaters were much appreciated by engineer, was evident, as it was now the general practice to provide feed heaters or economisers in all up-to-date boiler installations.

There were four systems of feed-heating—

(1) Feed heating by waste gases.

(2) Feed heating by exhaust steam.

(3) Feed heating by steam taken from the twin-pressure or intermediate receivers in compound engines.

(4) Feed-heating with live steam taken direct from the boiler.

The first system was represented by Green's and Lowcock's well-known types used in connection with land boilers, and Kemp's system used for marine boilers. The economy gained by the use of Green's and Lowcock's type varied from 12 to 20 per cent., depending on the ratio of economiser surface to boiler-heating surface, and also on the rate at which the boilers were driven.

In a boiler plant he had in his mind where the economiser surface was about 42 per cent. of the boiler-heating surface, the boilers being fairly hard driven, the temperature of the waste gases leaving the boiler was about 910° F., and after passing through the economiser the temperature was reduced to about 483° F. The class of fuel used in the boilers was wood and megass, the latter containing a considerable quantity of moisture, so that the temperature of the furnace would probably not be higher than from 21 to 2200° F., say 2150° F. Under these conditions of working the boiler only was utilising

$$\frac{(2150-910\times 100}{2150}$$

$=57{\cdot}67$ per cent. of the heat of combustion.

Assuming that no air leaked into the flue to dilute and cool the gases between the boiler and economiser, the increased efficiency due to the economiser was

$$\frac{(2150^\circ-483^\circ)\times 100}{2150}$$

$=77.5$ per cent., which was a gain of $77{\cdot}5-57{\cdot}67=20$ per nearly, due to the economiser. In this boiler plant the economiser was doing

$$\frac{20\times 100}{77{\cdot}6}$$

$=26$ per cent. of the total evaporative duty.

Kemp's system, as fitted on board the s.s. Cambric in 1888, consisted of four small multitubular boilers placed in the uptake. The gases, after leaving the main boiler tubes, passed through the tubes of the small boilers, which were arranged in series. The initial temperature of the gases entering the tubes of the heaters was 680° F., and, emerged at a temperature of 239° F., the gases were therefore cooled through a range of 680°—239°=441°. This vessel was fitted with forced draught, so that it might be assumed that the furnace temperature would range from 2300 to 2400° F. Under these working conditions the theoretical gain or saving by the use of the heaters was about 18·5 per cent., and in actual work the saving was found to be about 18 per cent.

The second system of feed heating by exhaust steam could only be used in connection with non-condensing engines. The direct saving to be effected by this system ranged from 10 to 14 per cent., as it saved or utilised heat which would otherwise go to waste. In addition to the direct gain or saving effected by utilising heat that would otherwise go to waste, there was an indirect saving or gain in economy from the increased efficiency of the heating surface of the boiler, due to pumping the feed water into the boiler at a higher temperature.

Most of the members were conversant with the theories which had been suggested to account for the increased efficiency of the boiler heating surface and gain in fuel economy resulting from the practice of pumping the feed water into the boiler at the highest practicable temperature. It should be remembered in this connection that the conductivity of water was only $\frac{1}{80}$ of that of iron, and that active circulation tended to increase the conductivity of the water. Experiments on this subject showed that the co-efficient of transmition of a given surface varied from 1 to 4 as the water in contact with the surface approached the boiling point or was actually boiling. It should also be remembered that any particle of fuel gases was only about one second in passing through the boiler, and that the greater the conductivity of the water by active circulation the more heat would be absorbed from the gases in a given time, and that should the conductivity of the water be lessened by pumping comparatively cold feed water into the boiler which interfered with the circulation, there would be less heat absorbed in a given time.

It should be noted that the makers of boilers of the water-tube and express types recommend fitting feedwater heaters in connection with their boilers if the highest economy was to be obtained, notwithstanding the fact that the circulation in these boilers was very active. This seemed a strong recommendation for feed heating. He thought it might be safely contended that whatever be the true explanation of the economy, direct and indirect, realised by feed-heating, its existence was beyond all doubt.

Referring to the first system mentioned, he would like to draw attention to the results of a test of steam boilers working with and without a Green's Economiser, recorded in Hutton's treatise on "Steam Boilers," page 137.

The figures showed an economy of 28·9 per cent. in favour of the economiser—although the heat absorbed by the feed water when passing through the economiser only accounted for about 12·5 per cent. leaving 28·9—12·5=16·4 per cent. to the credit of improved circulation, due to the higher temperature of feed water. In the test without the economiser, the difference between the temperature of the water in the boiler and the feed water being pumped into the boiler was 305″6—85°=220·6° F., and 305″6°—225°=80·6° F. when working with the economiser.

PARTICULARS OF TESTS.

	With Economiser.	Without Economiser
Duration of test in hours	$11\frac{1}{2}$	$11\frac{1}{2}$
Weight of coal consumed in lbs.	7856	10282
Working steam pressure in lbs.	58	57

Temperature feed-water entering economiser	88° F.	—
,, ,, ,, boilers	225° F.	85°
Number of degrees feed-water heated ...	137	—
Tempt. of fuel gases entering economiser ...	618°	—
,, ,, ,, ,, ,, chimney ...	365°	645
Number of degrees fuel gases cooled ...	253	—
Water evaporated per lb. coal for and at 212°	10·613	8·235
Saving effected by use of economiser ...	28·9%	

$$\frac{(10\cdot613-8\cdot235)\times100}{8\cdot235}=8\ 9\%$$

The economy due to the heat absorbed from the fuel gases might be computed as under :—

Each lb. of dry coal raised 10·613 lbs. of water from 88° to 305·6° and evaporated it into steam. (priming or moist steam not allowed for). The heat absolved was therefore 10·613+(3056—88)+10 613(1207·2—305·6)=1187th units in both economiser and boiler. The heat absorbed by the economiser only was 10·613 (225° – 88=1454 thermal units.

Then 1454×100÷11877=12·5° of the total evaporation. Then 28·9—12·5=16·47 of the economy was due to the increased absorbing power of the water on account of the more active circulation.

The third system was used principally in marine practice. The direct saving to be effected had been clearly demonstrated to range from 5 to 8 per cent, depending on the steam pressure in the boiler, and also whether one or two heaters were used.

The fourth system, that of heating the feed-water by steam taken direct from the boiler, seemed at first sight to offer no advantage so far as economy was concerned, as the heat in the steam used for heating the feed had already been paid for in the shape of coal burned to produce it. The economy of the system had, however, been clearly established.

The well-known French engineer, J. A. Normand, found a saving of 20 per cent. when the feed temperature was raised to

240° F. in boilers of the express type which was generally hard driven. The Normand heater was surface type. The Kirkaldy Compactum Patent "Feed water heater" was one of the best known types of surface heaters, and was much used in the mercantile marine and the navy.

There were other types of surfaces heaters which consisted of one or more tubes placed inside the steam space of the boiler. They all, however, acted on the same principle.

There were other types of live steam feed heaters which heated the feed water by contact—that was to say, the steam in the boiler and the feed water came into contact either inside the boiler or in a separate vessel immediately alongside the boiler. The "Hanna Spray" and the "Acme" were two of the types placed inside the boiler, the former by a spray only, the latter by surface heating and spray combined, and the Babcock & Wilcox and Stirling types were two excellent types arranged in seperate vessels attached to the boilers. About 15 years ago the "Acme" type of live steam feed heater was brought under the notice of the general manager of the Colonial Sugar Company by an American engineer, who offered to fit it to one of the company's boilers at his own expense, so that it could be thoroughly tested. His offer was accepted, the tests lasted for about two months, and showed an increased boiler efficiency of about 15 per cent. where the feed water was pumped into the heater at 130° F., and about 10 per cent. when the water was pumped into the heater at 166° Fah. The temperature of the water in the boiler was from 316° to 320° F. The water was carefully measured in a specially calibrated tank. The blow-off cock and other connections from which leakage could take place were blanked. The same class of coal was used throughout the tests, and was carefully weighed. He had had considerable experience in fitting live steam heaters to many classes of boilers, always with the same results—a decidedly